DEPARTMENT OF GEODETIC SCIENCE

Second Quarterly Progress Report

DATA ANALYSIS IN CONNECTION WITH THE NATIONAL GEODETIC SATELLITE PROGRAM

by

Ivan I. Mueller and Richard H. Rapp

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PREFACE

This Report was prepared by Ivan I. Mueller (Principal Investigator), Associate Professor and Richard H. Rapp (Co-investigator), Assistant Professor of the Department of Geodetic Science at The Ohio State University. The execution of this research is under the technical direction of the Director, Physics and Astronomy Programs, and of the Project Manager of the National Geodetic Satellite Program, both at NASA Headquarters, Washington, D. C. The contract is administered by the Office of Grants and Research Contracts, Office of Space Science and Applications, NASA, Washington, D. C.

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1. STATEMENT OF WORK

Conduct the first year of a multi-year study and analysis of data from satellites launched specifically for geodetic purposes and from other satellites useful in geodetic studies. The program of work follows the proposal #36-008-(033) and includes analysis of positions derived from photographic observations of both reflecting and emitting satellites, from range observations, and from any other suitable types of observation. The final analysis will be an improved map placing all participating tracking stations on a single world-wide coordinate system. In deriving the final results, the Ohio State University representatives work with representatives of universities and other government agencies to prepare a single handbook compiling the best geodetic data available at the time.

The work during the first year includes, but is not limited to, the following:

Task 1: Programming, testing, debugging of analysis methods.

Task 2: Participating in working groups and other planning meetings to establish desirable operational procedures including tracking procedures, participants' selection, data format, communication procedures, analysis procedures, etc.

Task 3: Providing advice to NASA on various aspects of the National Geodetic Satellite Program.

2. PERSONNEL

Ivan I. Mueller, Associate Professor, Principal Investigator, 20% time,

Richard H. Rapp, Assistant Professor, Co-investigator, 20% time,

Edward J. Krakiwsky, Research Assistant, 50% time, Hans D. Preuss, Research Assistant, 50% time,

John R. Miller, Technical Assistant, 50% time,

Jeanne C. Preston, Secretary, 75% time.

3. REPORT ON TASK NO. 1

3.1 THE DATA ANALYSIS COMPUTER PROGRAM

In order to utilize the data that will be obtained under the National Geodetic Satellite Program, a formulation of the use of this data and the subsequent programming of the equations had to be carried out. The outline of this program in terms of its operations, input and output information, has been previously described in the last Quarterly Report. As originally envisioned, this program was written in single precision arithmetic or about eight decimal places. Later consideration showed that some computations must be done in double precision (sixteen digits) in order to assure full retention of observational accuracy. In general, the computations not done in double precision are those involving coefficients in the observation equations used in the adjustment scheme. The conversion to double precision has considerably improved the reliability of the results we have obtained in testing the program.

3.2 PROGRAM TESTING AND RESULTS

3.21 Data Generation. It is apparent in a program of the size involved in this contract that extensive testing needs to be carried out. This testing should represent the actual situation as well as possible. It is thus important to generate data that would resemble observed data. There are two types of data that need to be generated: 1. direction observations (right ascension and declination), and 2. range. A computer program has been written (in double precision) to generate such quantities given the following information:

1. Orbital elements (six elements in series form as given in the form of the Smithsonian Astrophysical Observatory),
2. Stations observing satellites (latitude, longitude, elevation),
3. Times of observation.

The output of this program yields the observed right ascension and declination, and the range at the given time. This information is punched in the appropriate format for use as input to the main program in the form desired.

The above description would yield exact generated data. In other words, given the input circumstances the output values would be true. However, there are many corrections that go into the actual data, as well as the observational errors themselves. We can neglect the corrections because we absorb them into our model, but we can not realistically drop the observational errors. To this end we attach errors to the exact generated data. This is done by knowing the standard error of an observation (for example, ± 4" for directions, and ± 10 m for range) and using this in conjunction with a random draw for a normally distributed population with mean = 0 and variance = 1. This latter element is available through a subroutine written at The Ohio State University Computer Center.

We are thus able to arrive at a set of generated data which resembles observational data, and can be used with reliance in the testing of the main program.

3.22 Sample Program Tests.

3.221 Simultaneous Directions. One of the options in the main program is the utilization of simultaneous direction observations. The concept of this testing is to use appropriate station coordinates for the unknown stations. The approximate coordinates are chosen by adding small corrections to the coordinates of these stations that have been used in the generation above. If the program is working successfully, the adjusted coordinates should agree (within a certain degree) to the coordinates used in the generation. In addition, the standard errors of the adjusted coordinates should be consistent with the standard error assumed for the generated observations.

The specific example chosen, in its most general form, used five stations with thirteen sets of simultaneous sightings. Though simultaneous sightings from five stations is not a common occurence, the example is valuable for the variety of cases that may arise. The results from this test, keeping three of the stations unknown, are shown below.

Station		$\Delta\varphi$	$\Delta\lambda$	ΔH
2	true	$-10''.00$	$0''.00$	0.0 m
	program	$-10.38 \pm .29$	$-0''.07 \pm .26$	5.8 ± 17.9
3	true	$-30''.00$	$-30''.00$	-99.0 m
	program	$-30''.74 \pm .37$	$-29''.82 \pm .47$	-91.7 ± 19.9
4	true	$-15''.00$	$-10''.00$	-25.0 m
	program	$-14''.99 \pm .52$	$-9''.82 \pm .53$	-5.4 ± 21.0

The true value represents the expected correction based on the modification of the coordinates used in the data generation, while the values given under "program" are those that have been returned (with their standard errors) from the computer programs. The results are in good agreement with the standard errors. We can thus conclude that the computer program is working satisfactorily for the case of simultaneous direction observations.

3.222 Simultaneous Ranging Observations. The computer program has been arranged to accept directly ranging observations. We have chosen the same example as described above for the generation of ranging data assuming a standard error = ± 10 m for one measurement.

At the present time no satisfactory results have been obtained from the ranging example. We have used four points with three of them assumed fixed. Problems have arisen in the determining of the matrix of the normal equations, it being singular, or near singular, for several test cases. This problem could arise from poor station geometry or a program error. Studies are continuing to eliminate this problem.

3.223 Datum Connections. As part of the computer program, various datum connections may be made. In order to test this feature, the data on two different datums, must be generated with known translations and rotations. Computations have been started on the generation of such data, which will subsequently be used in the main program.

4. REPORT ON TASK NO. 2

Dr. Mueller participated in the discussions on December 13, 1965 at NASA Headquarters.

Mr.Preuss attended the Western National Meeting of the AGU on September 1 - 3, 1965 at Dallas.

Several meetings were held with Wolf Corporation and System Sciences Corporation.

5. REPORT ON TASK NO. 3

Upon the request of Dr. N. Roman, Program Scientist, a tentatively proposed observation plan for the geometric analysis was prepared. The plan, presented in Figure 1 and the accompanying tables, is based on the USC&GS primary network. To this net several optical stations were added with the following missions:

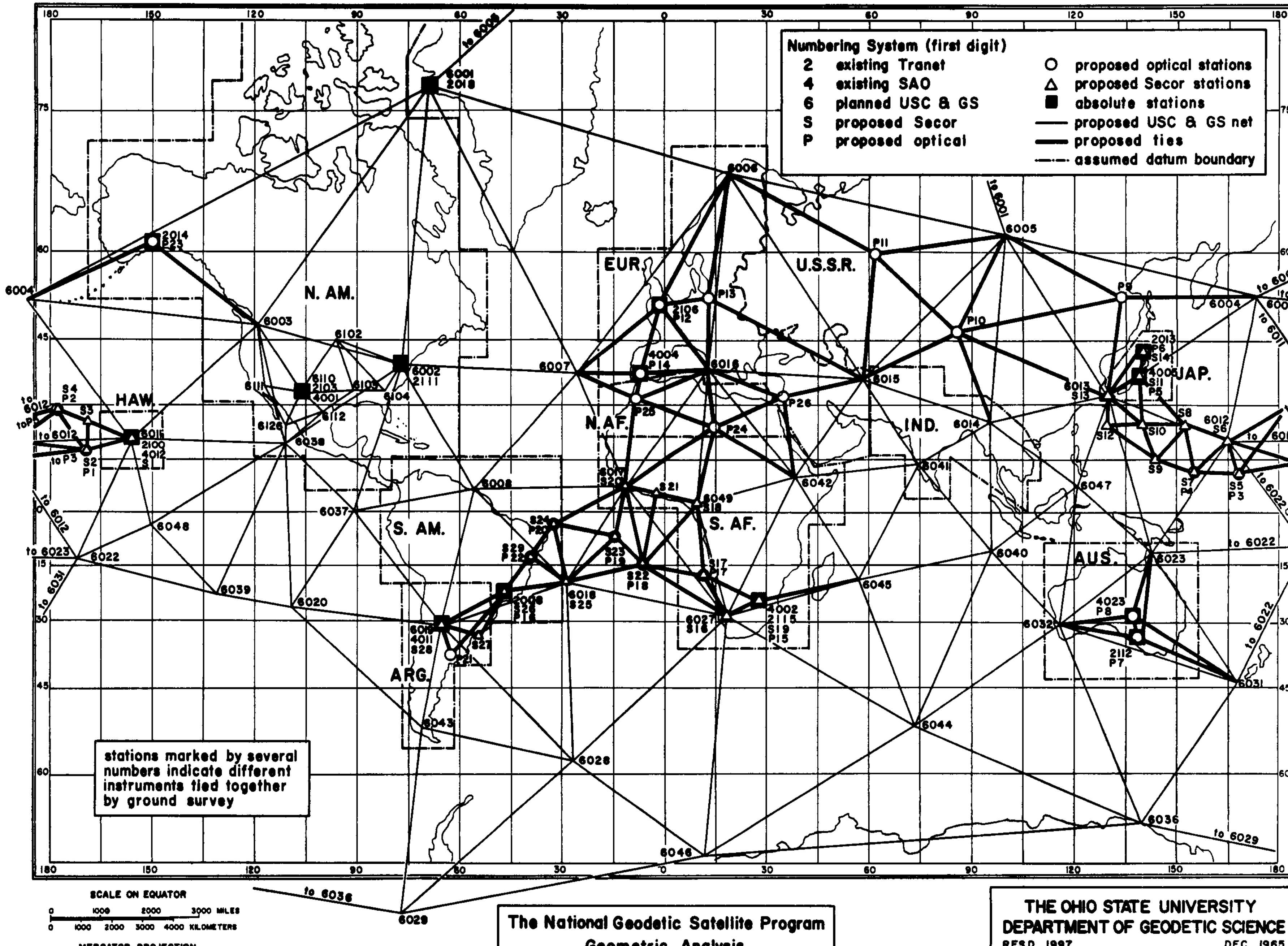
1. To have at least two optical stations on each geodetic datum as shown on the map (The boundaries of the datums and their completeness need to be investigated),
2. To establish an optical line interwoven within the proposed SECOR net (see below),
3. To provide ties between our "absolute" stations and the network.

Two bands of SECOR stations were also proposed, in the vicinity of the equator, to be used as spatially oriented baselines between points in South America and Africa, and also between Japan and Hawaii.

The absolute stations, which will be used to translate and rotate the relative (optical - secor) network, as described above, to the geocenter, consist of TRANET and Baker Nunn sites. These stations naturally need to be tied to the relative network.

The tables after the figure speak for themselves.

PROPOSED OBSERVATION PLAN



The National Geodetic Satellite Program
Geometric Analysis

THE OHIO STATE UNIVERSITY
DEPARTMENT OF GEODETIC SCIENCE
RFSD 1997 DEC. 1965
IVAN I. MUELLER

Proposed Stations in Addition to the USCGS Primary and Secondary Net as Indicated on the Map

OSU No.	*identical or to be tied	OSU No.	*identical or to be tied
S1	6011,2100,4012	P1	S2
S2	P1	P2	S4
S3		P3	S5
S4	P2	P4	S7
S5	P3	P5	4005, S11
S6	6012	P6	2013, S14
S7	P4	P7	2112
S8	5507	P8	4023
S9	5508	P9	
S10		P10	
S11	4005, P5	P11	
S12		P12	2106
S13	6013	P13	
S14	2013, P6	P14	4004
S16	6027	P15	4002,2115,S19
S17	P17	P16	2008,S26
S18	6049	P17	S17
S19	4002,2115,P15	P18	S22
S20	6017	P19	S23
S21		P20	S24
S22	P18	P21	
S23	P19	P22	S29
S24	P20	P23	2014
S25	6018	P24	
S26	2008, P16	P25	
S27		P26	
S28	6019, 4011		
S29	P22		

*The station numbers refer to Goddard Space Flight Center, Geos-A Project OCE-Data Systems Division - NASA, Tracking Complement October 12, 1965; USCGS primary and secondary net and OSU proposed stations.

U. S. C. &G. S. Proposed Primary Net Stations that have to Observe Simultaneously with OSU Optical Stations as Listed Below*

U. S. C. & G. S. primary stations	OSU proposed optical stations
6003	P 23
6004	P 9, P 23
6005	P 9, P 10, P 11
6006	P 11, P 12, P 13
6007	P 12, P 14, P 25
6011	P 1, P 2
6012	P 1, P 2, P 3, P 4,
6013	P 5, P 6, P 9, P 10
6014	P 10
6015	P 10, P 11, P 13, P 26
6016	P 12, P 13, P 14, P 24, P 25, P 26
6017	P 18, P 19, P 20, P 24, P 25
6018	P 16, P 18, P 19, P 20, P22
6019	P 16, P 21
6023	P 7, P 8
6027	P 15, P 17, P 18
6031	P 7, P 8
6032	P 7, P 8
6042	P 24, P 26
6045	P 15
6049	P 17, P 18, P 24

* If the U. S. C. & G. S. can not observe simultaneously for logistical reasons these sites must be reoccupied.

List of Identical Instrument Locations or Which Need to be Tied Together by Ground Survey

Location	SAO	TRANET	USC&GS	Proposed	
				secor	optical
Hawaii	4012	2100	6011	S1	
N. Mexico	4001	2103	6110		
Alaska		2014			P23
Greenland		2018	6001		
Maryland		2111	6002		
Argentina	4011		6019	S28	
Brazil		2008		S26	P16
England		2106			P12
Spain	4004				P14
South Africa	4002	2115		S19	P15
Mizusawa, Japan		2013		S14	P6
Tokyo, Japan	4005			S11	P5
Smithfield, Australia		2112			P7
Woomera, Australia	4023				P8
Johnston Islands				S2	P1
Pacific				S4	P2
Pacific				S5	P3
Pacific			6012	S6	
Pacific				S7	P4
Japan			6013	S13	
South Africa			6027	S16	
South Africa				S17	P17
Africa			6049	S18	
Africa			6017	S20	
Saint Helena Island				S22	P18
Ascension Island				S23	P19
Rocas Island				S24	P20
Trinidad Island			6018	S25	
Brazil				S29	P22

The station numbers refer to Goddard Space Flight Center, Geos-A Project OCE-Data Systems Division - NASA, Tracking Complement October 12, 1965; USC&GS primary and secondary net and OSU proposed stations.

Approximate Number of Observations Required
From the Various Networks

	Network	Observational Requirements
Absolute Stations	SAO	Data from stations indicated on the map for approximately two years of observations on satellites of various inclinations.
	TRANET	Data from stations indicated on the map at intervals of 20 to 60 seconds for approximately three to four months per satellites of various inclinations.
Relative Stations	Optical stations observing passive satellites with the modified Wild BC-4 camera (e.g., USC&GS)	Three to seven simultaneous observations between stations as indicated on the map.
	Optical stations observing flashes or single satellite images (e.g., PC 1000)	Twenty five to fifty simultaneous observations between stations as indicated on the map.
	Secor	Selected aggregated data from twenty five to forty passes per observing group of four stations each.

For the Department of Geodetic Science

Project Supervisor Ivan I. Mueller Date 12.29, 1965

For The Ohio State University Research Foundation

Executive Director Robert C. Stephenson Date 12/27, 1965